

(19) World Intellectual Property Organization
International Bureau



(10) International Publication Number
WO 2012/003134 A3

(43) International Publication Date
5 January 2012 (05.01.2012)

(51) International Patent Classification:
G05B 13/04 (2006.01)

(21) International Application Number:
PCT/US201 1/041723

(22) International Filing Date:
24 June 201 1 (24.06.201 1)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/829,523 2 July 2010 (02.07.2010) US

(71) Applicant (for all designated States except US): **WOODWARD HRT, INC.** [US/US]; 25200 W. Rye Canyon Road, Santa Clarita, California 91355 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **PARK, Austin** [US/US]; 2817 N. Buena Vista St., Burbank, California 91504 (US).

(74) Agent: **THOMPSON, James, F.**; Bainwood, Huang & Associates, LLC, 2 Connector Road, Westborough, Massachusetts 01581 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(88) Date of publication of the international search report:
16 February 2012

(54) Title: CONTROLLER FOR ACTUATION SYSTEM EMPLOYING KALMAN ESTIMATOR INCORPORATING EFFECT OF SYSTEM STRUCTURAL STIFFNESS

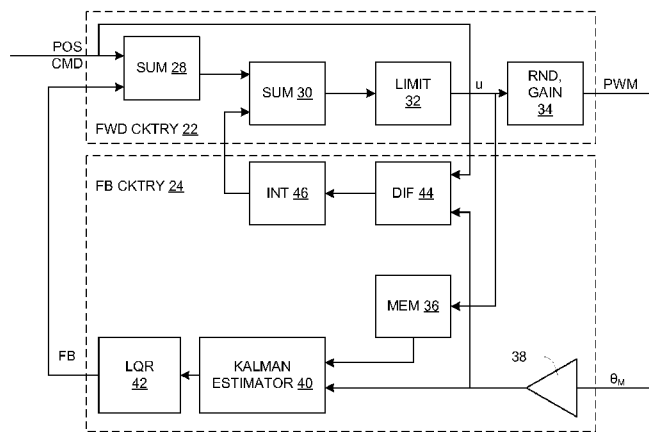


Fig. 4

(57) Abstract: A controller (14) for an electro-mechanical actuation system such as a missile fin (12) actuator includes a Kalman estimator circuit (40) which generates an estimate of operating state including position and velocity of motor (16), position and velocity of a position-controlled element (PCE) (10), and motor current. The estimate is generated based on a dynamic model explicitly including the effect of structural stiffness and damping in the coupling between the motor (16) and the PCE (10), for example by treating it as a mechanical oscillator having spring and damping constants. The Kalman estimator (40) operates on a motor drive control signal and a measured position signal which may be from a Hall sensor sensing motor position. A linear quadratic regulator circuit (42) generates a control effort signal by applying a state feedback gain matrix to a state vector. The state feedback gain matrix mimminizes a quadratic cost function representing variance of the control effort signal and/or the measured position signal.



WO 2012/003134 A3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/041723

A. CLASSIFICATION OF SUBJECT MATTER INV. G05B13/04 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) G05B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 564 H Q BI (MAKINO KENICHI [JP] ET AL) 13 May 2003 (2003-05-13) cited in the appl icati on col umn 2, line 58 - col umn 3, line 22 -----	1, 8
A	EP 1 298 053 A2 (COLTEC IND INC [US] GOODRICH PUMP & ENGINE CONTROL [US]) 2 April 2003 (2003-04-02) figure 1 -----	1. 8
A	W0 2007/092466 A2 (BAE SYS LAND & ARMAMENTS LP [US] ; SHOEMAKER JEFFREY W [US] ; LEWIS TIMO) 16 August 2007 (2007-08-16) page 7, line 18 - page 8, line 30 -----	1, 8
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family	
Date of the actual completion of the international search 14 December 2011	Date of mailing of the international search report 21/12/2011	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Kel peri s , K	

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 65641 10	BI	13-05 -2003	NON E

EP 1298053	A2	02-04-2003	DE 60205554 DI 22-09 -2005
			DE 60205554 T2 08-06-2006
			DE 602 14253 T2 14- 12-2006
			EP 1298053 A2 02-04-2003
			JP 2003 14817 1 A 21-05 -2003
			US 698664 1 BI 17- 01-2006
			US 200309400 1 AI 22-05 -2003

Wo 2007092466	A2	16-08-2007	US 2007296364 AI 27- 12-2007
			wo 2007092466 A2 16-08-2007
